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(54) Heat exchangers

(57) A ceramic heat exchanger shown in Figure 1 has a body having two sets of alternating flow channels, one for high pressure fluid and the other for low pressure fluid. One set has an inlet 6 in the top of the body at one end; this set has an outlet, not shown, at the other end 4. The other set has an inlet 12 in the top of the body at the other end; this set has an outlet at the end 5. The channels in Figure 1 are cut by milling. In other embodiments the body is formed either by extrusion or by lamination methods.

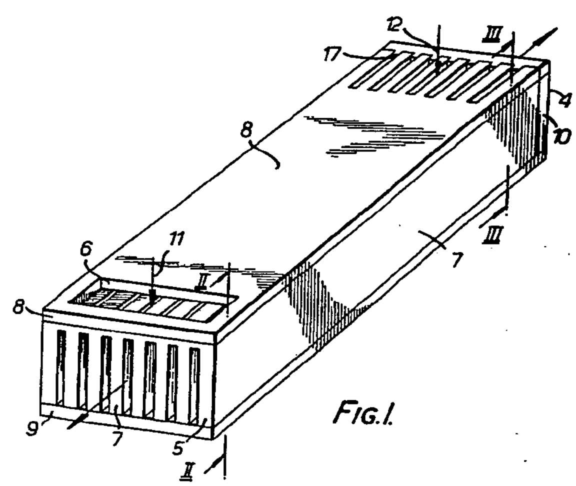

FIG.1

The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

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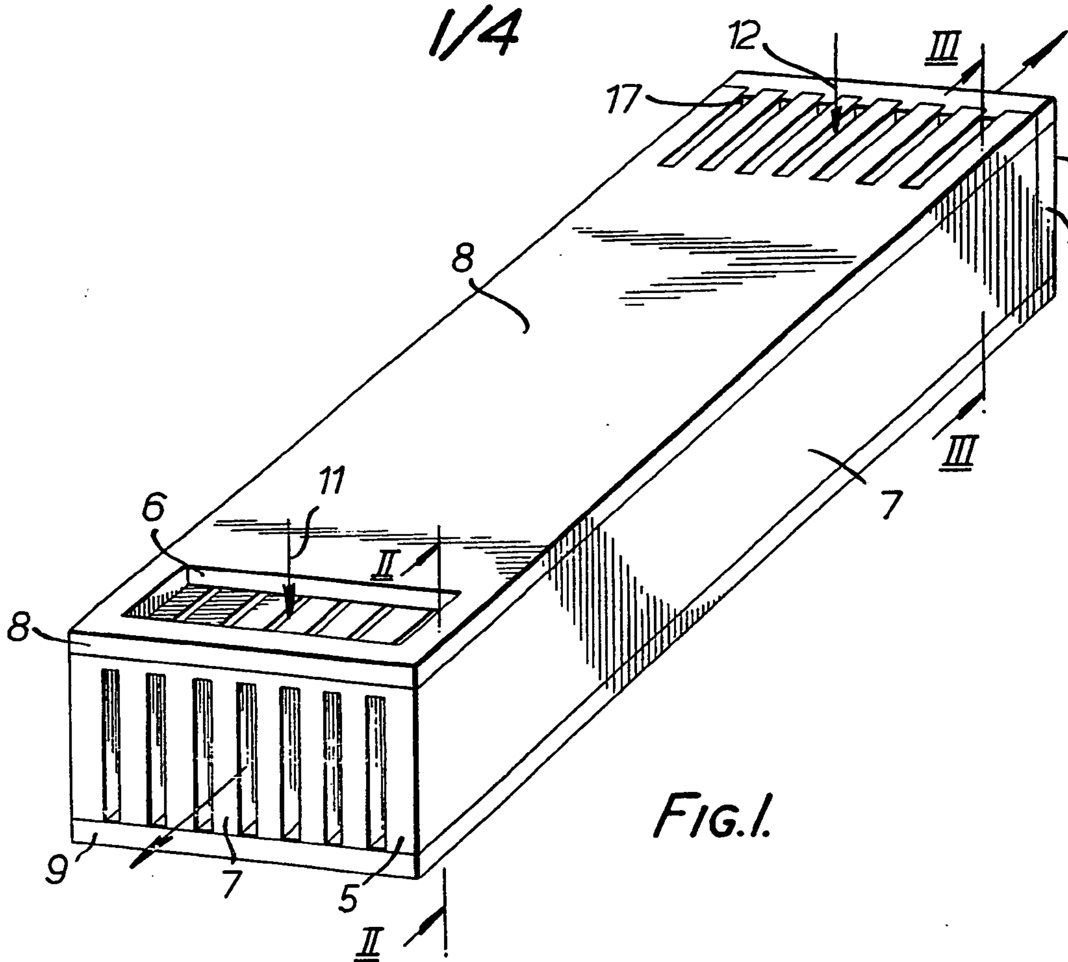

FIG.1.

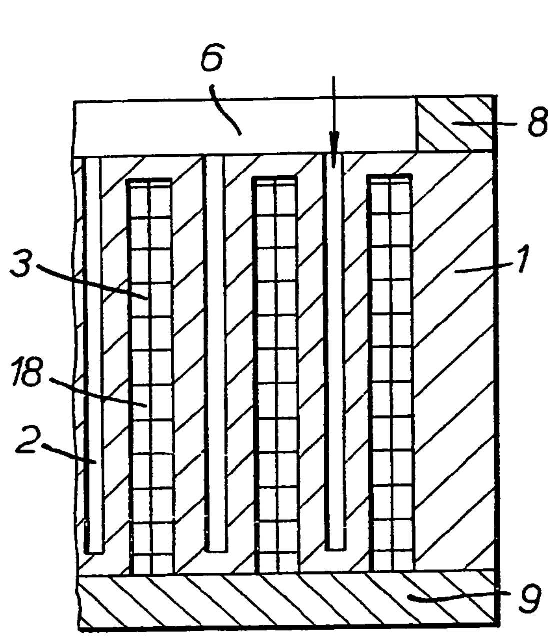

FIG.2.

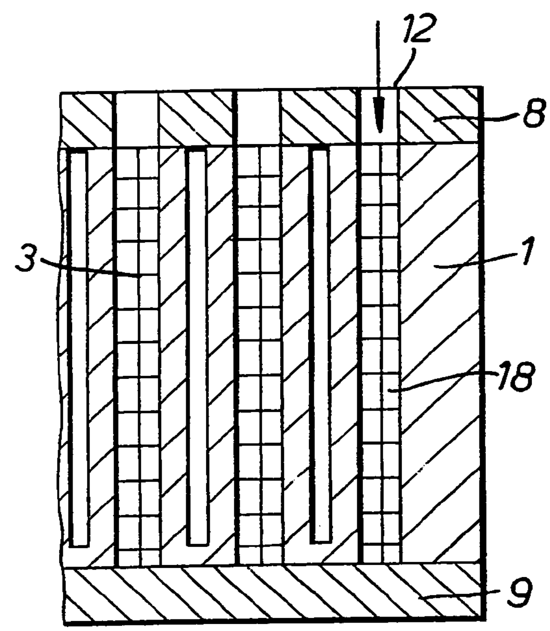

FIG.3.

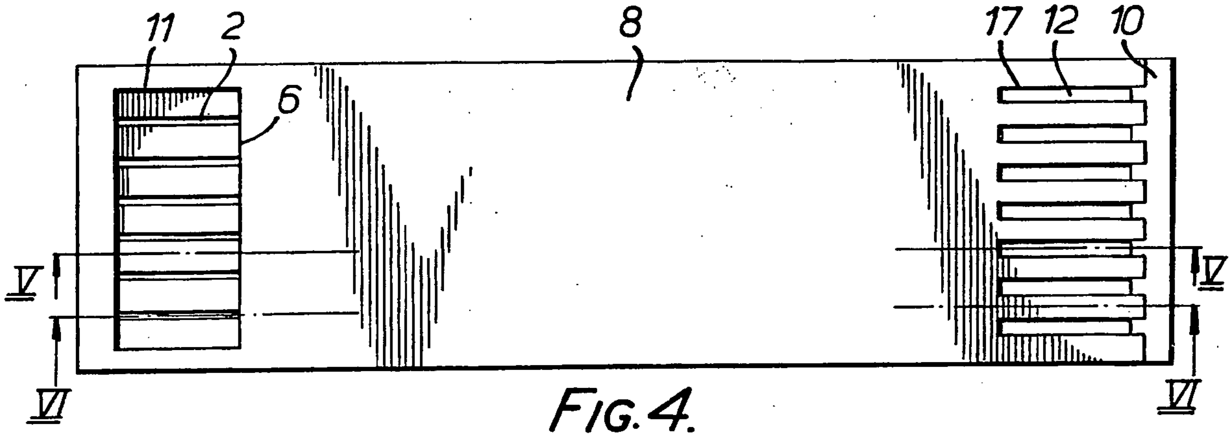

FIG. 4.

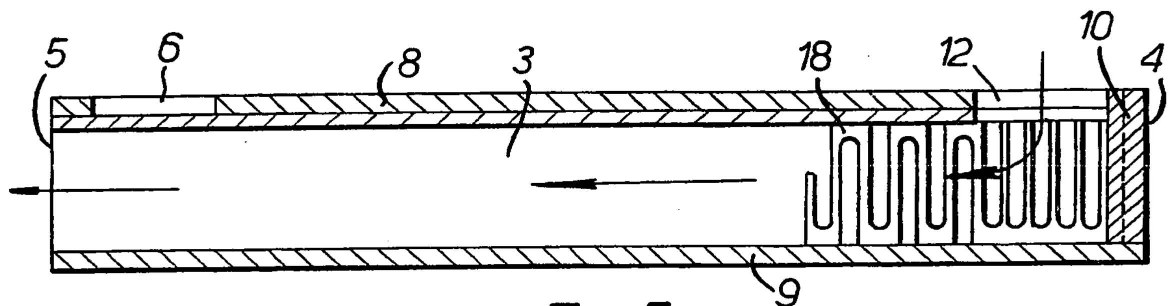

FIG. 5.

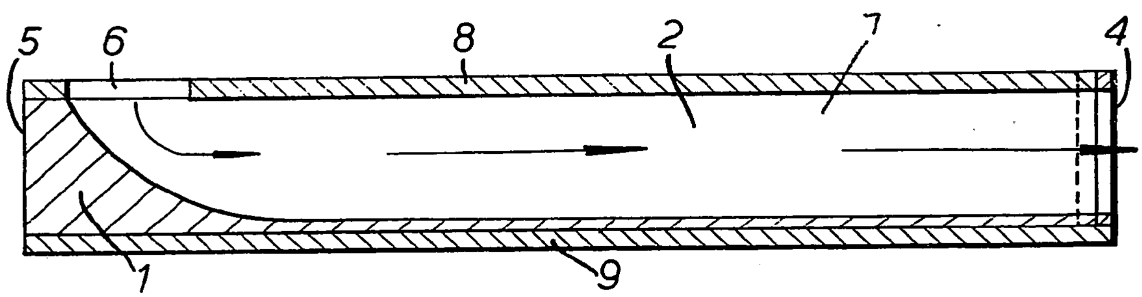

FIG. 6.

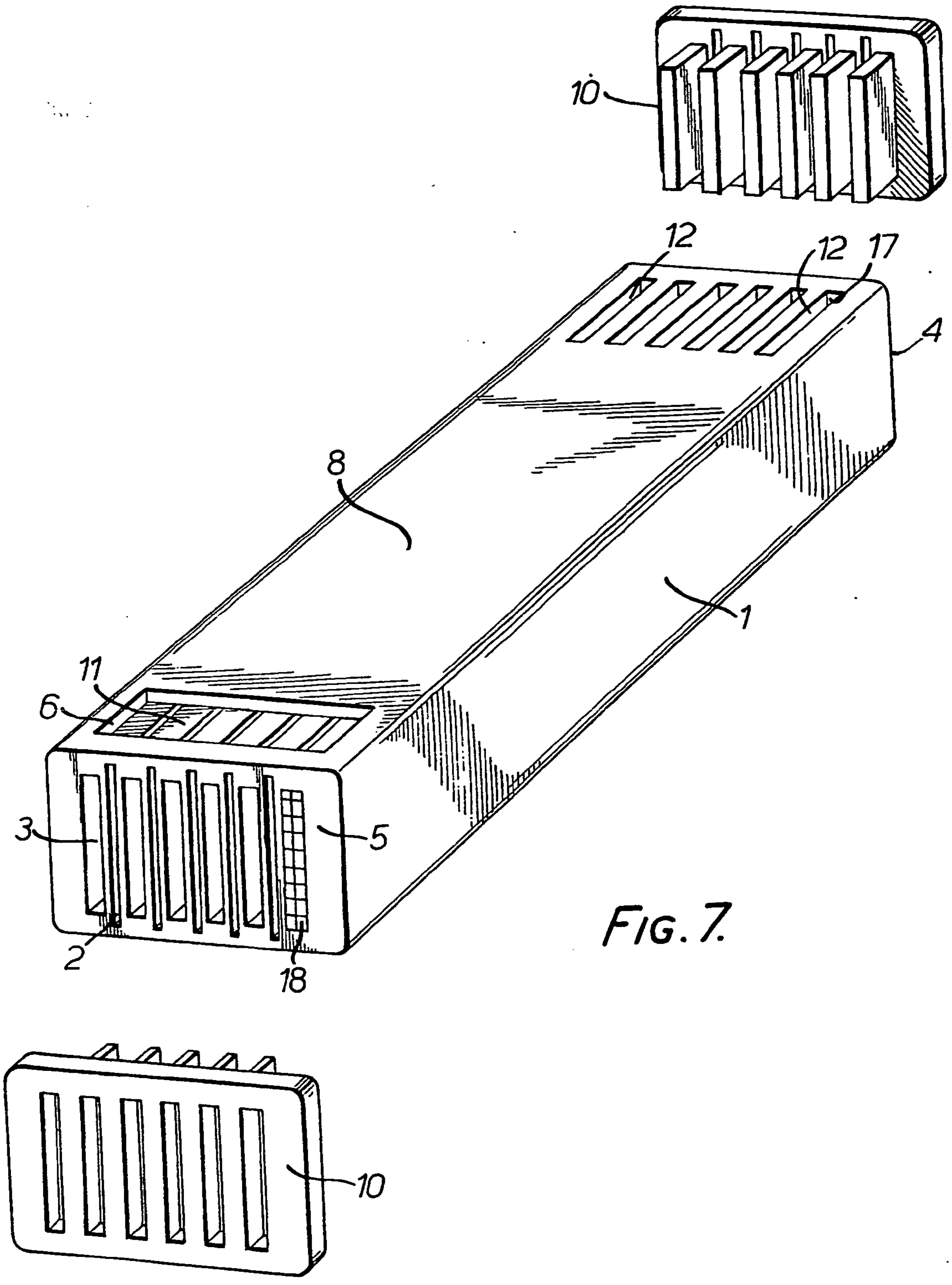

FIG. 7.

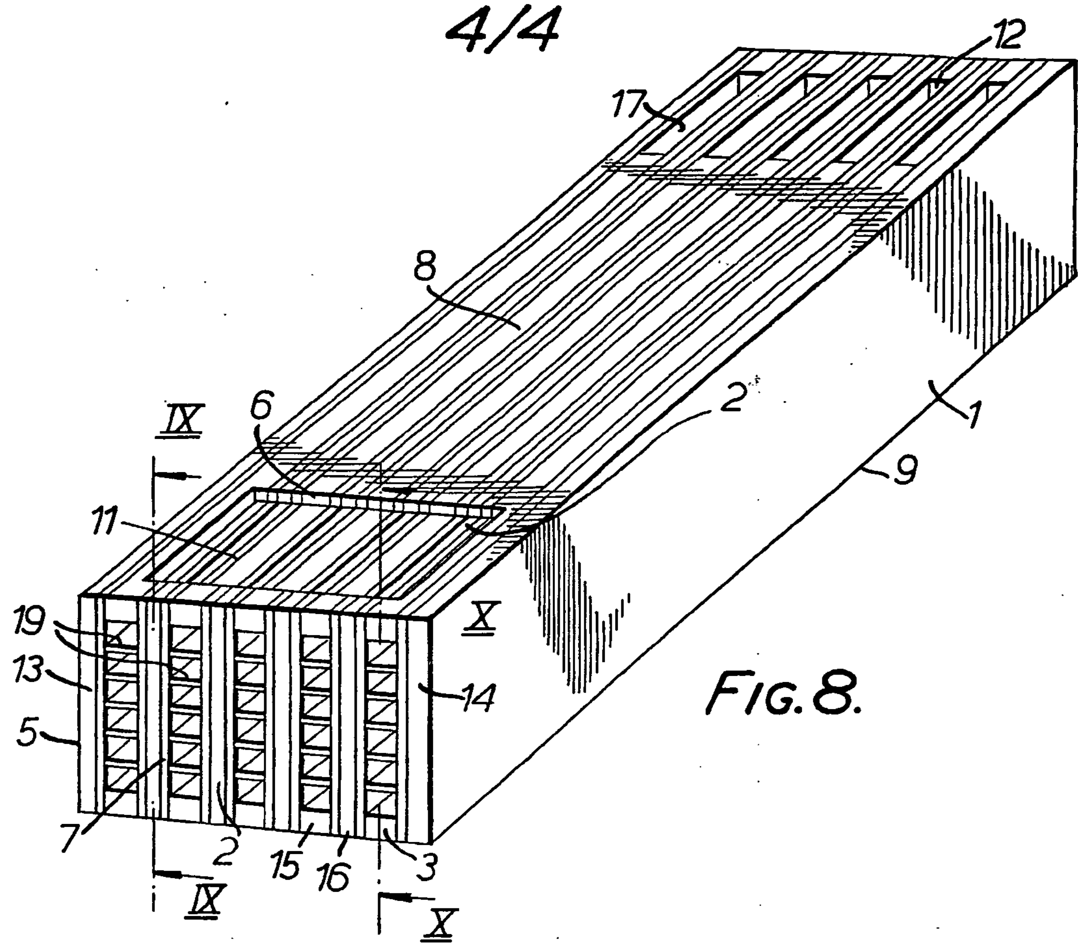

FIG. 8.

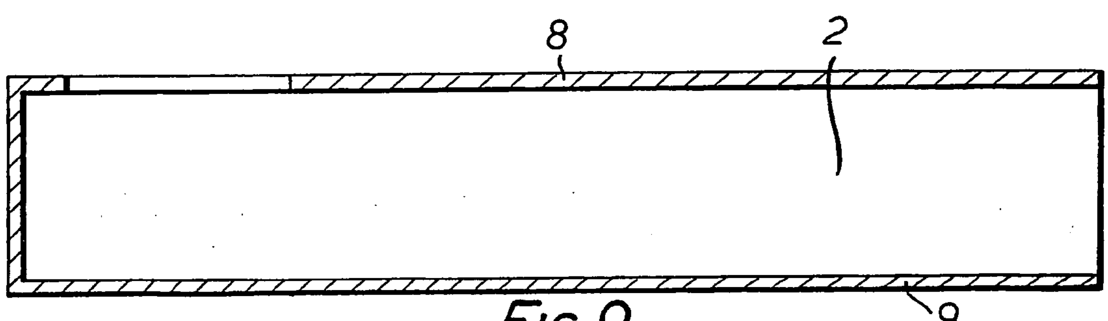

FIG. 9.

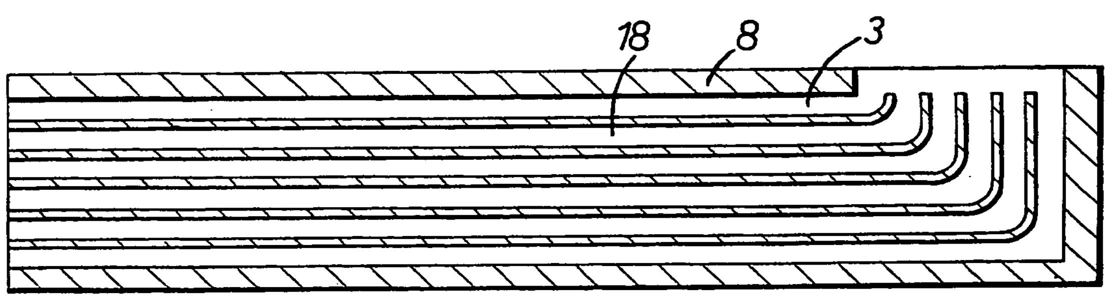

FIG. 10.

SPECIFICATION

Heat exchangers

This invention relates to ceramic recuperative heat exchangers. Recuperative heat exchangers are particularly suitable for gas turbines in which ceramic materials, such as silicon carbide, silicon nitride and cordiarite are used. In developing economic gas turbines for vehicles it is found that heat exchangers are required which can withstand gas temperatures of approximately 1300°C. For this reason, it is found that only ceramic materials can be considered as the heat exchange materials. It has been found that problems occur with regenerative heat exchangers having rotating ceramic discs and as a consequence, it has been found necessary to fall back on recuperative type heat exchangers. Heat exchangers suitable for this and other purposes should have a high degree of efficiency, be small in dimensions and light in weight. It is also necessary for such ceramic recuperative heat exchangers to function reliably and to be cheap to produce. One of the objects of the invention therefore is to provide a ceramic recuperative heat exchanger which can be easily provided with connections for heat exchange media.

According to the present invention a ceramic recuperative heat exchanger comprises an elongate body having two sets of flow channels for heat exchange media, the channels extending lengthwise of the body, and the channels of one set alternating with the channels of the other set and adjacent channels being separated by common walls, the channels of one set extending from an inlet or outlet in one end wall to an outlet or inlet which opens laterally from the body adjacent the other end wall, and the channels of the other set extending from an inlet or outlet in the other end wall to an outlet or inlet which opens laterally from the body adjacent the one end wall. The body may be generally rectangular in cross-section and have four lateral walls, the outlet(s) or the inlet(s) being formed in the same lateral wall. Alternatively the outlet or inlet for one set of channels may be in one lateral wall and the outlet or inlet for the other set of channels may be in another of the lateral walls.

Where the heat exchanger is to be used with high pressure media in one set of flow channels and low pressure media in the other set of flow channels it is desirable to include braces in the channels of the set which carry the low pressure media.

According to another aspect of the present invention, in a process for the production of a recuperative heat exchanger of the above type, the channels of one set are milled out of the body from one side in such a way that one end of the body is at this stage uncut, and the channels of the second set are then cut from the opposite side. In this case, after the channels of the one set are milled out, a covering wall may be applied to that side of the body and during cutting of the second set of channels, slits are cut through the covering wall to provide the laterally opening inlet or outlet to those channels.

In an alternative method of production of a recuperative heat exchanger a main part of the body is extruded and the first set of channels are formed by the extrusion process to a greater depth than the second set of channels and the main part is cut to length and a lateral opening for the first set of channels is cut in one end of a side face of the main part to a depth which extends into the first set of channels but not into the second set of channels, and slots are cut into the main part at its other end of a side face which provides a lateral opening into each of the second set of channels.

In a further alternative process the body is formed by fabrication from layers which include a pair of side plates with walls to the first and second sets of channels positioned between the side plates and separated at upper and lower extremeties by distance pieces. In this case the distance pieces for the first set of channels are preferably shallower than the distance pieces of the second set of channels and a lateral opening is cut in one end of the body to give access to the first set of channels by cutting to a depth which removes entire portions of the distance pieces lying in those channels but leaves intact portions of the distance pieces lying in the second set of channels, and laterally opening slots are cut at the other end of the body, each slot being of a width substantially equal to the width of the channels of the second set and of a depth at least equal to the depth of the distance pieces lying in the channels of the second set.

The invention may be carried into practice in a number of ways but several specific embodiments will now be described by way of example with reference to the accompanying drawings, in which:-

Figure 1 is a perspective view of a heat exchanger forming one embodiment of the invention;

Figure 2 is a scrap sectional view on the line II in Figure 1;

Figure 3 is a scrap sectional view on the line III in Figure 1;

Figure 4 is a plan view of the heat exchanger of Figures 1 to 3;

Figure 5 is a sectional side elevation on the line V-V of Figure 4;

Figure 6 is a sectional side elevation on the line VI-VI of Figure 4;

Figure 7 is a perspective view of a second embodiment;

Figure 8 is a perspective view of a third embodiment;

Figure 9 is a sectional side elevation on the line IX-IX of Figure 8, and

Figure 10 is a sectional side elevation on the line X-X of Figure 8.

The first embodiment, which is illustrated in Figures 1 to 6, comprises an elongate rectangular section ceramic heat exchanger which basically comprises a heat exchanger body or block 1 in which parallel flow channels 2 and 3 are arranged side by side and are separated by common walls 7. In this embodiment, the flow channels 2 comprise the high pressure side and have a slot width of 0.8 mm whilst the channels 3 comprise the low pressure side and have a slot width of 1.6 mm. The channels 3 on the low pressure side are preferably strengthened by braces 18. These produce, due to the numerous

re-tions in cross section, high rates of flow and eddying which bring with them an effective increase in heat transfer. The heat exchanger is completed by upper and lower walls 8 and 9 respectively and a comb-like end piece 10 at one end. A flow 11 of high pressure fluid is introduced into the channels 2 via a window 6 provided in the upper wall 8 adjacent the left hand end of the heat exchanger in Figures 1, 4, 5 and 6. This fluid moves rightwards through the heat exchanger and leaves it through slits provided in the end piece 10 which forms the end wall 4 at the right hand end of the heat exchanger.

The other fluid flow 12 enters the channels 3 via slots 17, again formed in the upper wall 8, this time adjacent the right hand end 4 of the heat exchanger. The flow of fluid entering the slots 17 and passing through the channels 3 leaves the left hand end 5 of the heat exchanger by virtue of the fact that the channels 3 extend the full length of the block 1 forming the body of the heat exchanger. Whilst the specific embodiment shown in Figures 1 to 6 has the window 6 and the slot 17 formed in the same wall, i.e., the upper wall 8 of the heat exchanger, they may, if desired, be formed one in the upper wall 8 and one in the lower wall 9 of the heat exchanger.

The individual parts of the heat exchanger are advantageously made from ceramic materials such as silicon nitride, silicon carbide or cordierite which in the fired state can withstand high temperatures of 1300°C and higher and which are also characterised by a good temperature shock resistance. It is found that the higher temperature resistance of this design offers potential uses which are not possible with metal heat exchangers. Individual production stages and measurements of the various parts must be carefully co-ordinated so that production reaches the highest possible technical standards and economy.

The heat exchanger of the first embodiment of Figures 1 to 6 is produced by machining for which silicon nitride is a particularly suitable material. The process commences with an isostatically pressed and nitrated block into which the flow channels 2 are first cut with diamond grinding wheels. These enter the block from the side which will eventually be provided with the upper wall 8 and are cut in the manner shown in Figure 6 in such a way that the front end 5 of the block remains closed for the time being and the slots extend from a curved wall 2A in Figure 6 to the end of the block 4 at the right hand end. In order to obtain slot widths which are as uniform as possible, and to prevent the dividing walls 7 from breaking, the grinding dust is immediately blown out by a jet of compressed air provided near the cutting point. This causes additional cooling so that the thermal stress in the grinding wheel is reduced. Both the individual covering walls 8 and 9 and the co-operating faces of the block 1 have been previously ground with parallel co-operating faces. The window 6 is cut in the covering wall to serve as the inlet for the high pressure fluid into the high pressure flow channels 2. The upper wall 8 is then fitted so that the window 6 is located adjacent the end 5 which is still closed.

The block 1 with the upper wall 8 is then inverted so that the wall 8 is downwards and the block is placed on a milling cutter and the flow channels 3 of the low pressure side are cut into the opposite underface of the block. The channels 3 are cut completely through the block from one end to the other and after the braces 18 have been introduced, for example, from the side through which the cutting blades enter to form the channels 3, the comb-like end piece 10 is provided which blocks off the flow channels 3 but leaves the flow channels 2 of the high pressure side open to the end 4 of the heat exchanger. The final stage is the fitting of the lower wall 9 and the heat exchanger is then completed by nitrating between 1350° and 1500°C.

Figure 7 shows an alternative embodiment of heat exchanger according to the invention, the body of which is produced by extrusion techniques. The particular construction of the flow channels 2 and 3 is obtained by the use of corresponding cores in the nozzle of the extrusion press. The nozzle can, for example, be constructed so that wide flow channels 3 and somewhat deeper, narrower, channels 2 are formed. The required length of heat exchanger is then cut from the extrusion and the inlet opening 11 in the form of a window 6 is obtained by exposing the flow channels 2 through the covering wall 8 by cutting to a depth which does not expose the flow channels 3.

At the other end, the flow channels 3 are provided with inlets 12 by milling slots 17 in the direction of the flow channels near to the end 4. Clearly the slots 17 have to be milled to a depth greater than the depth of the window 6 in order to open the slots 17 into the channels 3. Finally, the comb-like end pieces 10 are fitted onto the two ends 4 and 5 in order to complete the two L-shaped conduits for the heat exchange media. The heat exchanger thus produced is then subjected to a sintering process.

Figures 8, 9 and 10 show a third embodiment in which a heat exchanger is produced by forming a stack of individual rectangular or square sheets. Thus this construction comprises a pair of side walls 13 and 14 of a closed nature between which punched sheets 19 are provided in spaced relation, the sheets being alternately spaced by deep distance pieces 15 and shallow distance pieces 16. The distance pieces 15 and 16 are either extruded or isostatically pressed. In this embodiment, the upper and lower faces 8 and 9 are not provided by separate walls but are formed by the upper faces of the side walls 13 and 14 and the interposed sheets 9 and the distance pieces 15 and 16.

The window 6 which provides access into the high pressure flow channels 1 is preferably milled to such a depth that the distance pieces 16 in this region are removed, but not to a depth to remove the distance pieces 15 in this region.

At the other end, the slots 17 are milled in line with the wider flow channels 3 to a depth to remove the distance pieces 15 in these regions, thus providing the inlet 12 into the low pressure side of the heat exchanger.

The overall strength of the heat exchanger block is obtained by subjecting it to a hot or cold lamination process. During hot lamination, temperatures between 80 and 150°C are reached and a moderate

pressure of about 20 Kg/cm^2 is used in order to bond the parts together. During cold lamination on the other hand, the pressure must be considerably higher, for example, between 40 and 200 Kg/cm^2, but individual layers have to be provided with a plastic layer beforehand so that the bonding effect is produced. The body is then subjected to a conventional sintering process. Although this involves somewhat higher production costs than extrusion, it has the advantage that the shaped braces 18 can be inserted in the direction of the gas supply as shown in Figure 10.

The production of the ceramic heat exchangers according to the invention is not restricted to the methods of production described above but can also use a combination of machining and extrusion press techniques. Such production methods make it possible to manufacture heat exchangers in ceramic material, both cheaply and reliably. By specific construction of the inlet and outlet openings to the heat exchanger the heat exchanger can be connected, for example, directly, i.e., without arranging resilient strain relief means, to the duct of a gas turbine. Because of the relatively cheap starting materials the heat exchanger can be produced economically.

CLAIMS

1. A ceramic recuperative heat exchanger comprising an elongate body having two sets of flow channels for heat exchange media, the channels extending lengthwise of the body, and the channels of one set alternating with the channels of the other set and adjacent channels being separated by common walls, the channels of one set extending from an inlet or outlet in one end wall to an outlet or inlet which opens laterally from the body adjacent the other end wall, and the channels of the other set extending from an inlet or outlet in the other end wall to an outlet or inlet which opens laterally from the body adjacent the one end wall.

2. A heat exchanger as claimed in Claim 1 in which the body is generally rectangular in cross-section and has four lateral walls, the outlet(s) or the inlet(s) being formed in the same lateral wall.

3. A heat exchanger as claimed in Claim 1 in which the body is generally rectangular in cross-section and has four lateral walls, the outlet or inlet for one set of channels being in one lateral wall and the outlet or inlet for the other set of channels being in another of the lateral walls.

4. A heat exchanger as claimed in any one of the preceding claims including braces in the channels of one set.

5. A process for the production of a recuperative heat exchanger as claimed in any one of Claims 1 to 4 in which the channels of one set are milled out of the body from one side in such a way that one end of the body is at this stage uncut, and the channels of the second set are then cut from the opposite side.

6. A process as claimed in Claim 5 in which, after the channels of the one set are milled out, a covering wall is applied to that side of the body and during the cutting of the second set of channels, slits are cut through the covering wall to provide the laterally opening inlet or outlet to those channels.

7. A process for the production of a recuperative heat exchanger as claimed in any one of Claims 1 to 4 in which a main part of the body is extruded and the first set of channels are formed by the extrusion process to a greater depth than the second set of channels and the main part is cut to length and a lateral opening for the first set of channels is cut in one end of a side face of the main part to a depth which extends into the first set of channels but not into the second set of channels, and slots are cut into the main part at its other end of a side face which provides a lateral opening into each of the second set of channels.

8. A process for the production of a recuperative exchanger as claimed in any one of Claims 1 to 4 in whch the body is formed by fabrication from layers which include a pair of side plates with walls to the first and second sets of channels positioned between the side plates and separated at upper and lower extremeties by distance pieces.

9. A process as claimed in Claim 8 in which the distance pieces for the first set of channels are shallower than the distance pieces of the second set of channels and a lateral opening is cut in one end of the body to give access to the first set of channels by cutting to a depth which removes entire portions of the distance pieces lying in those channels but leaves intact portions of the distance pieces lying in the second set of channels, and laterally opening slots are cut at the other end of the body, each slot being of a width substantially equal to the width of the channels of the second set and of a depth at least equal to the depth of the distance pieces lying in the channels of the second set.

10. A heat exchanger substantially as described herein with reference to Figures 1 to 6 or Figure 7 or Figures 8 to 10 of the accompanying drawings.

11. A process for the production of a recuperative heat exchanger substantially as described herein with reference to Figures 1 to 6 or Figure 7 or Figures 8 to 10 of the accompanying drawings.

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